Forest Disturbance Mapping with Sentinel-2 Time Series in Austria

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Worldwide, forests provide natural resources and ecosystem services. However, forest ecosystems are threatened by increasing forest disturbance dynamics, caused by direct human activities or by altering environmental conditions. It is decisive to reconstruct and trace the intra- to transannual dynamics of forest ecosystems. Therefore, the monitoring of large and small scale vegetation changes such as those caused by natural events (e.g., pest infestation, higher mortality due to altering site conditions) or forest management practices (e.g., thinning or selective timber extraction) becomes more and more crucial. National to local forest authorities and other stakeholders request detailed area-wide maps that delineate forest disturbance dynamics at various spatial scales.

We developed a time series analysis (TSA) framework that comprises data download, data management, image preprocessing and an advanced but flexible TSA. We use dense Sentinel-2 time series and a dynamic Savitzky-Golay-filtering approach to model robust but sensitive phenology courses. Deviations from the phenology models are used to derive detailed spatiotemporal information on forest disturbances. In a first case study, we apply the TSA to map forest disturbances directly or indirectly linked to recurring bark beetle infestation in Northern Austria.

In addition to spatiotemporal disturbance maps, we produce zonal statistics on different spatial scales that provide aggregated information on the extent of forest disturbances between 2018 and 2019. The outcomes are (a) area-wide consistent data of individual phenology models and deduced phenology metrics for Austrian forests and (b) operational forest disturbance maps, useful to investigate and monitor forest disturbances, for example to facilitate sustainable forest management.

At a forest stand level, we reconstruct the origin date of forest disturbances (FDD – Forest Disturbance Date). Theses FDD outputs show the spatiotemporal patterns and the development of damages and indicate that most dynamics are caused by recurring and spreading bark beetle infestation. The validation results based on field data confirm a high detection rate and show that the derived temporal information is reliable. In total, 23400 hectares, i.e., on average 2.8% of the forest area in the study area, are found to be affected by forest disturbance. The zonal statistic maps point out hotspots of significant forest disturbances, where adequate forest management measures are highly needed. Furthermore, this study highlights the TSA’s potential to also depict and monitor minor human impacts on forests, such as thinning, selective timber extraction or
other moderate forest management practices.

**Keywords:** forest disturbance; forest monitoring; bark beetle infestation; forest management; time series analysis; phenology modelling; remote sensing; satellite imagery; Sentinel-2